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TEMISTOCLE CALZECCHI ONESTI (1853-1922), THE COHERER, THE SCIENTIFIC ALPHABETIZATION OF UNITA

The discovery

It does not appear that Hertz ever took an interest in new telecommunications technology, even though his experiments opened the possibility of transmitting signals remotely, wirelessly, involving a larger operating community than strictly scientific.

In truth, an attempt was made to cite as a proof of his interest a letter written in 1899 to a Munich engineer who had questioned him about the possibility of transmitting sounds by means of em waves. The physicist replied that the acoustic vibrations are too slow to be able to be irradiated directly in the form of electric waves: at the frequency of 1000 cycles per second, which corresponds to a wavelength of 300 km, reflectors would be required capable of covering an area of a few million square meters, almost a continent like Europe.

Hertz did not address at all the more general question of the realization of a wireless telegraphy system (TSF)

It may be thought that he would also have answered this question negatively, and not only because he had completed his task, which was to scientifically solve a problem posed by other scientists. Hertz's resonator was of an attractive and harmonious simplicity; but it was made to measure for his laboratory, and the sparks of reception could only be observed within that perimeter. Much more sensitive electric wave detectors already existed, but their peculiar function had not yet been recognized. It is thus understood that technological creativity was to follow scientific creativity, so that the possibility indicated by science became a concrete realization of a TSF system

The operation of the detectors mentioned above was based on the variation of the conductivity of various species of imperfect electrical contacts, which are located in the joints of microphones or in the body of dust and metal filings, when they are subjected to various types of electrical actions, but mainly to the action of Hertzian waves.

These are devices discovered and rediscovered several times before reaching the general attention. Already in 1835 PS Munk af Rösenschold, of the University of Lund, had reported the sudden increase in the conductivity of a mixture of thin metal filings, coal and other conductors, placed between an iron and a lead electrode and crossed by the current of discharge of a bottle of Leiden.

We will fly over the works of the American SA Varley, who in 1852 observed a sudden fall in the high resistance of metal powders, under the action of thunderstorms, and of the other American (transplanted to England) D. Hughes. It suffices to recall here that Hughes, professor of music and talented technologist, author of a writing telegraph that was well received in France (1860), in 1877 made a fundamental contribution to the nascent telephony: the device which was then called `microphone '. Hughes's device ended up replacing Edison's carbon microphone; and moreover that microphone was a sensitive detector of em waves, by virtue of the two imperfect contacts made in M and N by the stick C which is housed there with a certain play (fig. 1).

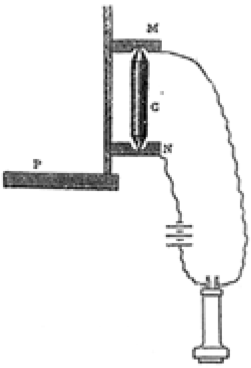


Fig.1 - Hughes' microphone

Along with the microphone described in the text, the telephone receiver patented by Graham Bell (1876) is visible in the stack circuit. The current modulated by the microphone reaches the receiver, and runs through the coils of an electromagnet placed in front of a thin iron sheet. The vibrations induced in the latter reproduce the sound that generated the microphone current. In the Bell system the receiver also works as a microphone.

According to Bernard Dessau [609] "the merit, if not the first discovery, at least of a systematic investigation and carried out independently of his predecessors, belongs to the Italian professor Calzecchi Onesti, whose experiences were published in 1884 and in 1885" [610]

One can share Dessau's claim that Professor Calzecchi was not aware of the discoveries of his predecessors: he would have otherwise mentioned them. Instead, he knew Hughes's microphone well, which in his first scientific work (published in 1881 on the "Nuovo Cimento") described as follows:

"The coal, which is very mobile between the two bearings of coal, moving insensibly and differently for all the sounds, even extremely small ones, which are produced around him, is a cause of continuous change in the resistance of the circuit and consequently in the intensity of the current. .. ".

It is the clear prose with which it refers to a work done in the Physics Laboratory of the Royal Technical Institute of L'Aquila [611] . Calzecchi had arrived there in 1879, after graduating in Mathematical Physics from the University of Pisa, and after a brief period of assisting with the physicist Riccardo Felici. Felici is known for his experimental research on electromagnetic induction; and the familiarity shown later by Calzecchi with the phenomena of induction can be ascribed for some part to the attendance of Professor Felici.

From the considerations made on the functioning of the microphone the young teacher and researcher deduced that any body, at once sonorous and conductor, and arranged in the same way as Hughes' bar of charcoal, in a state of vibration would have transmitted the sounds produced by its own vibrating . The behavior of a sonorous metal cord confirmed his predictions; likewise the transmission of the music of a harp, whose strings had inserted in the usual telephone circuit.

He was thus able to declare himself confident of realizing a faithful transmitter of all sounds, and in particular of the voice, following the procedure of Graham Bell.

What we said can explain the subsequent research program on conducting metal filings, made by Calzecchi in the Physics Laboratory of the Regio Liceo di Fermo, where he had moved in 1883.

The Frenchman M. Ader had successfully modified Hughes' microphone, multiplying the carbon rods and the contacts (fig. 2); Professor Calzecchi may have thought of increasing the sensitivity of the microphone analogously through the numerous imperfect contacts that form in metal powders.

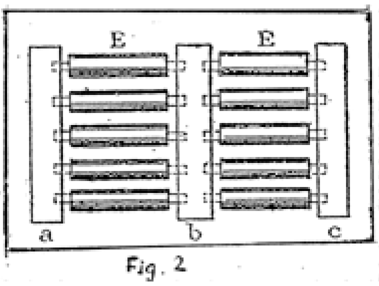


Fig. 2 - Ader rod microphone

It is also possible that he intended to continue the research of Augusto Righi, on the modulating effects of conductive powders [612] ; the two hypotheses are not incompatible, if Calzecchi really wanted to make a high performance microphone.

In the first *memoir* sent to the "Nuovo Cimento" in 1884, he accurately described, in meticulous experimental style, the results of his investigation. In a cannellino closed at the ends by two identical metal rings, he had placed copper filings and other conductors distributed continuously between the two electrodes, so that it retained a certain freedom of movement. Two metal support columns were in direct contact with the ferrules, and were connected to two wells of mercury by means of conductive wires (fig.3).

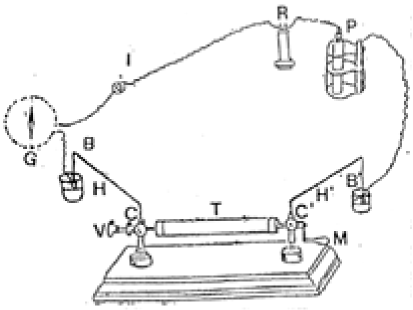


Fig.3 - First experience of Calzecchi

Description : T è un cannellino di ebanite o di vetro chiuso all'estremità da due cappelletti cilindrici C,C', il primo dei quali può togliersi girando la vite V. Per mezzo di una manovella M il cannellino può girare attorno all'asse C C' ed è messo nel circuito della pila P, del ricevitore telefonico R e del galvanometro G [bussola delle tangenti] mediante i due gossi fili H e H' che vanno a pescare nel mercurio contenuto nei due bicchieri B e B'. All'inizio quando si chiude il circuito con il bottone I, G non segnala alcun passaggio di corrente. Estraendo rapidamente il reoforo PB' da B e riportandolo in B', T viene reinserito, ma il passaggio di corrente persiste; e la corrente si fa più intensa ripetendo il gioco. La rapida estrazione del reoforo da B' e da B è accompagnata dallo scintillio delle extracorrenti.

A galvanometer, a telephone receiver and a key were also closed on the wells, in series with some Leclanché battery elements. In this way, through the contacts in the mercury, the filings, the galvanometer and the telephone could form a closed circuit, in series with the battery. When the circuit was closed, the galvanometer did not signal any current flow; to verify that this was due to the high resistance of the filings, Sock the excluded from the circuit, detaching from a column the communication wire with the corresponding pit, and immersing the free end of this wire in the other well. In the closed circuit, from which the cannellino was excluded, the galvanometer signaled the passage of a considerable current, confirming the high resistance of the filings;

In his *memory* , Calzecchi did not explain the reason for the presence of the telephone receiver, presumably of the Bell type, which is superfluous for the purposes of the experiment. But the instrumental disposition was that adopted by Hughes in his research on microphone contacts; it is therefore possible to explain the presence of the telephone with the analogous researches planned by the professor from the Marche. Whatever the reason for its presence, the telephone proved to be very useful: the numerous turns of the telephone receiver give the circuit a high inductance, so that the discharges produced by the extracurrents, which are formed by closing and above all sharply opening the circuit are amplified.

Familiarized with those phenomena with Pisan experiences, Calzecchi quickly understood the new role of the telephone; and replaced it with an induction coil, inserted in parallel with the tube circuit, with a hammer switch which had the task of causing, with its interruptions, the self-induced excitation discharges of the filings (figs. 4 and 5).

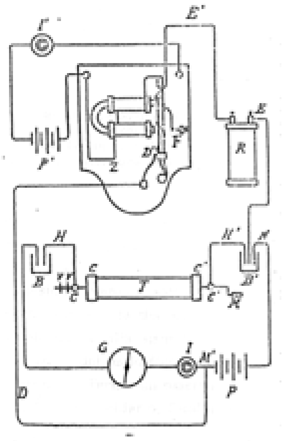


Fig.4 - Second experience of Calzecchi

Description - The phone of the first experience is replaced by the spool (winding) R, inserted in the PNB'ERE'D'DM'P circuit, derived from the P battery parallel to the PNB'TBGIM'P tube circuit. The hammer switch Z is fed separately from the battery P 'through the button I' and the intermittent contact F. By pressing the button I ', the hammer is attracted by the electromagnet crossed by the current; in f there is a spark when the contact opens, due to the winding of the magnet, which in the meantime is de-energized. The hammer is recalled in F and in D 'body a strong spark, due to the spool R. The sparks are due to the conspicuous increase in conductivity of the filings.

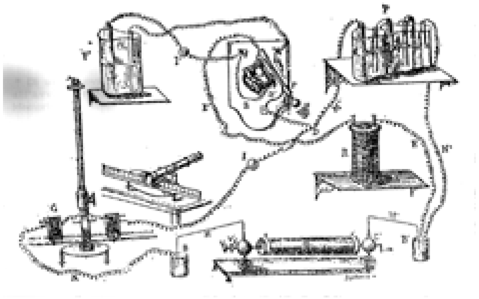


Fig.5

The drawing reproduces the scheme of fig.4. T is the cannellino, G a Kelvin galvanometer with movable needle, with two windings, a mirror integral with the needle and reading with projector and graduated scale. R is a spool, P 'consists of a stack element Leclanché, P with three elements; Z is the hammer switch; B, B 'are dimercurium wells, for the insertion of T into the circuit of the P stack.

The professor also experimented with other ways to achieve the cohesion [613] of filings, such as the influence of the electrostatic machine and temporary contact with an electrified body.

And he noticed another property: the state of cohesion fades under the mechanical action of shocks or vibrations. At the beginning Calzecchi obtained the decohesion with a few turns of the tube; then proposed an application to seismology, a `microseismic warning device 'sensitive to the minimum vibrations of the ground (fig.6). This was in agreement with those interests that made Fermo establish a meteorological observatory and a meteorological service for the whole district, based on the methods of statistical meteorology.

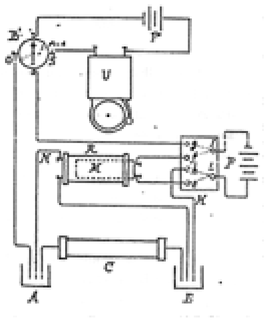


fig.6

"Of a new form that can be given to the microseismic signaler" (III Memory)

The tube C is alternatively inserted in the circuit comprising the bush B '(BLhDCAB'gIP), or in the circuit of the bobbin R fed to the stack P, by the action of the switch H. The conductivity of the filings is triggered by pulses of current of the stack P in the primary M of the spool; the shock (microsism) causes the de-cohesion, and the needle of the compass tends to return to its natural position; but it is stopped by the rod S which closes the ringing circuit U.

Calzecchi wrote, in his third *memoir* "A tremor that is communicated to the tablet that holds the cannellino, a small chorister that makes itself vibrate leaning against the same tablet, and sometimes a note that you sing, are enough to remove the conductivity from the filing". There is only one step to the automatic non-variation: just place an electric bell on the tablet provided by Calzecchi, driven by the current of the conducting tube, as Oliver Lodge would have done, a decade later.

With the discovery of the action of extracurrents on the powdery mass of the filings, and of mechanical non-cohesion, the search for Calzecchi ended.

Scientific teaching in post-unification Italy

The state of cultural backwardness of the Italian nation at the time of Unity can be summarized with these figures: in 1861, out of a population of about 26 million inhabitants, illiteracy affected 75 percent of individuals over the age of 6; 40,000 were the people who enjoyed secondary education, including the upper one, and the university students numbered 9,000 for nineteen universities, which became twenty-one with the new offices in Padua (1866) and Rome (1871).

Multiple historical and economic studies have also documented the distressing conditions from which the first industrial development of a united Italy began, the recurrent crises, the conspicuous delay with respect to the European reality.

As far as physical science is concerned, there was no lack of great scholars, such as Carlo Matteucci (1811 - 1868), who was one of the founders of modern electrophysiology. Matteucci became Minister of Public Education in 1862, in the Rattazzi government, and attempted to promote an education reform through a teaching body composed of well-known scholars and well-trained young people. A reform far ahead of its time, but which had the merit of spreading awareness of the Italian delay. Next to Matteucci one could name Father Angelo Secchi, who extended the field of astronomy by starting the spectroscopic study of stellar physics; and Enrico Betti, eminent physicist and mathematician of the Pisan Studio. Under the direction of Betti and the already appointed Riccardo Felici,

As we have said, in Pisa he studied and formed Themistocles Calzecchi Onesti together with Oreste Murani, his fellow countryman.

Murani, a good experimental physicist, switched from teaching in the technical institutes of Chieti (1878) and of L'Aquila (1883) to the Royal Technical Institute "Carlo Cattaneo" of Milan, and in Milan he entered the reality of the Higher Technical Institute, the future Polytechnic, also becoming the author of numerous manuals of the well-known Hoepli series.

But in truth, as Galdabini and Giuliani have shown [614] , a community of physicists, in the years of post-unification Italy, did not exist; instead there was a small group of almost isolated scientists, who faced a formidable challenge with inadequate material and cultural means. There was no theoretical physics: and this also prevented the interpretation and evaluation of the results obtained by the experimenters.

And yet a process of industrialization was starting, despite the persistent pockets of backwardness and the unresolved problem of the South. And in parallel to it there was a slow but sure increase in scientific knowledge and the spread of technical skills, so much so that it was possible to find the workers capable of supporting the productive development that accelerated after the 1980s.

Where then were the laboratories, where did the research take place, who prepared the workers, if university research and teaching were lacking in terms of quality and quantity?

Giorgio Dragoni pointed out that, until the early twentieth century, a great deal of good research was carried out in the secondary school laboratories [615] . The technical-scientific literacy, parallel to literacy *tout court* , was largely facilitated by the fact that numerous men of science found themselves operating in secondary schools, mainly because the economic treatment of middle teachers was almost equated with that of university professors, while the treatment of university assistants was insufficient, and their future was uncertain.

We have seen Calzecchi and Murani take their place in secondary education; but also Carlo Matteucci, Enrico Betti, Adolfo Bartoli and Orso Mario Corbino taught for some time in middle schools. And Antonio Pacinotti was a teacher of Augusto Righi at the Technical Institute of Bologna; in the high school of Livorno, Vincenzo Rosa, an electrical engineer and friend of Galileo Ferraris, was the first and only teacher of Guglielmo Marconi.

Many other scientists could be mentioned, and not only among those who later achieved a university professorship. And it is also true that the secondary school laboratories allowed scientifically and technically valid researches, if not of the highest level, as seen for the work of Calzecchi at the Technical Institute of L'Aquila and at the Liceo of Fermo.

The positivistic culture proclaimed the absolute centrality of laboratory practice; and learning through sensory education, which replaced verbal education, formed to concreteness and caution; he also started to clearly describe reproducible observations, to verify laws, to measure physical constants, to produce tables and graphs for engineers and technicians.

The particular Italian reality, made up of local academies and philanthropic and humanitarian projects, did the rest: the technical institutes, which constituted the privileged channel for access to technical and scientific faculties, were also subsidized by the institutions of their districts. And in the town hall many initiatives arose, mostly driven by the full awareness of the delay to be filled; initiatives that were often partial and uncoordinated, but that ended up globally converging in a propulsive push. At the same time, many secondary schools were equipped with research cabinets and adequate scientific equipment.

Calzecchi was a teacher for intimate predisposition; and in his pedagogical writings, beyond the pure positivistic method, we can grasp the unconditional appreciation for mathematical formation, and above all a humanism of high religious inspiration. After research on the filings, he left the laboratory, but only to undertake the rehabilitation of two deaf-mute girls. The expertise in the field of acoustics, which transpires from his research on microphones, inspired i

Themisticles Calzecchi Onesti

methodical exercises to which the two girls submitted, and the positive results were recognized at the prestigious Landes-Taubstummenschule in Vienna. Nor did he escape burdensome administrative duties, on behalf of the municipalities of Fermo and Monterubbiano. Alongside other researchers with whom he shared methods and ideals, he fully reflected those models of nineteenth-century culture in which the rationality of scientific research could not be separated from civil and social commitment. Calzecchi, like other intellectuals and contemporary scientists, was a researcher and, at the same time, a teacher and educator; the strong moral demands of his century demanded this integration between pure research and its applications, for the improvement of human life.

Thus it was that Hertz's research failed to reveal to Calzecchi, taken by other cures, the secret of cannellino; nor did Calzecchi read the summaries of the brief notes that the French physicist Edouard Branly had communicated to the Academy of Sciences in Paris on the "Nuovo Cimento" [616] .

In those notes we read: "If you replace a circuit that includes a Daniell element, a galvanometer [...] a tube with filings [...] often does not pass current. But an abrupt variation in resistance occurs [...] when one or more electric shocks are reproduced near the circuit ". At this point we would expect a quotation. But Branly did not mention Calzecchi, or other predecessors, either on that occasion, or later, when he greatly extended his sore experiences, and isolated the role of the spark as the cause of cohesion.

Dessau states that Branly "rediscovered the pipe-snout with no previous knowledge"; and it is true that no evidence of the contrary is known. But some doubts remain. It cannot be said that the communications of Calzecchi Onesti remained limited to the sphere of the readers of the "Nuovo Cimento": Professor Felix Auerbach of Wroclaw, on the prestigious "Wiedemann's Annalen" discussed the existence of a critical density for the cohesion of filings, alleged by Calzecchi. Physicist Bouty gave a concise but precise account of Calzecchi's discovery in the "Journal de Physique" for the years 1885-86, and that newspaper was regularly read in Paris.

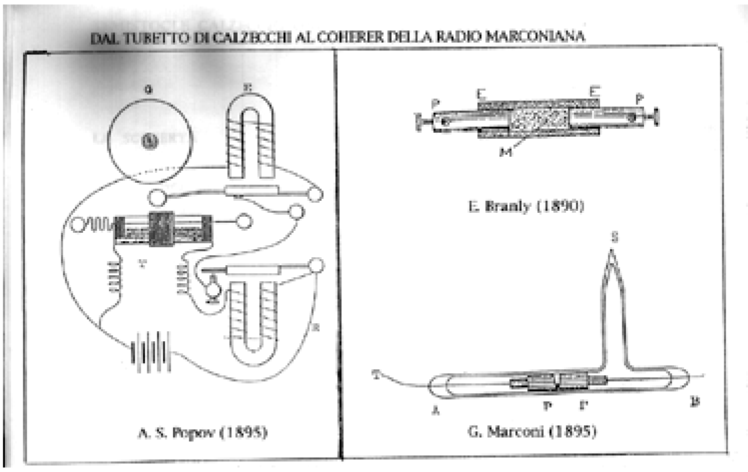
Calzecchi claimed his priority in 1897, with a letter to the "Nuovo Cimento". A question arose that embittered the professor from the Marches until his death in 1922. The question degenerated into chauvinistic brawl when, during fascism, the myth of the moral, civil and scientific primacy of the Italians was fed also by prestigious men of science [617] .

Even today, an authoritative treatise on general and experimental physics such as that of Eligio Perucca associates coherer with Calzecchi alone, and the equally authoritative treatise by Fleury and

Mathieu speaks of Branly alone.

In the 1985 edition of the well-known Hugh Aitken *Syntony and Spark* volume , we read that Marconi had no difficulty in obtaining a Hertzian wave detector, because he had access to technical-scientific magazines and was sufficiently perceptive to note the articles published by Branly between 1890 and 1891. But in a note he adds: "The coherer was discovered almost simultaneously [618] by Professor Calzecchi Onesti of Fermo, Italy, and it may be (" and it may be ") that Marconi's knowledge of the device is from this source, rather than from Branly ".

Appendix



At the top right you can see the Branly tube and under the Marconian coherer. The very young inventor constantly modified and perfected the tube: he did the emptiness, he searched for the optimal dimensions, sifted the filings and varied the composition up to the last recipe: 95% of nickel and 5% of silver. But the coherer always remained a device as sensitive as it was capricious, and was quickly replaced in radio receivers by the magnetic detector of Rutherford and Marconi and by the Fleming diode.

On the left we see the detector inserted in the receiver of the Russian physicist AS Popov (1895). The coherer T is inserted in the circuit of a stack together with the electromagnet of a relay R. Under the action of a wave em the filings become conductive, in the electromagnet current passes and the anchor is attracted, thus closing the circuit of the electromagnet E, which attracts the hammer. As in an electric bell, the hammer hits the bell G; the circuit is opened in D and the hammer falls under its weight, striking the coherer which is thus brought back to its primitive state of non-conduction, and is ready for a new revelation cycle.

Popov used an antenna like the one found independently by Marconi for his electric shock receiver. But the first complete and publicly tested transceiver system is owed to the Bolognese inventor (1896). By stepping over every question of priority one can think that the radio has existed since the prehistory of humanity, in fantasies aimed at canceling the barriers of space and time, as evidenced by the persistent interest in telepathy. To its realization, inventors, technicians and scientists of all time unknowingly contributed. Marconi gave the last seal to this chain, definitively transforming the ancestral fantasy into technological and economic reality.

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[609] A.Righi, B.Dessau, *The wireless telegraphy* (Zanichelli 1903).

[610] The Memoirs published in the "Nuovo Cimento" by Calzecchi were actually three: *On the conductivity of metal filings* , "NC" series 3, XIII (1884) pp.58-64; the second, with the same title, in "NC" series 3, XVII (1885) pp.38-47; *Of a form that can be given to the* microseismic signaling device, in "NC", series 3, XIX (1886) pp.24-26 is the third, usually neglected by scholars.

[611] For what we will see, it is significant that Calzecchi expressed his gratitude to the Provincial Council of L'Aquila, which - he writes - "urged by public education, has provided and is providing the Physics Laboratory of the Royal Technical Institute, making it possible for me to establish scientific

research "(see *On the transmission of sounds in a telephone circuit operated by the same sound conductors,* " Nuovo Cimento, series 3, X, 1881, pp.237-239).

[612] In 1878 Righi had developed a telephone system that allowed to transmit and receive sounds at a certain distance from the microphone and the loudspeaker. Despite the technical success, his foray into the world of commercial electrical communications was short-lived. See: G. Tabarroni, *Bologna and the history of radiation* (Bologna, 1965).

[613] Oliver Lodge suggested that microwelds formed at the passage of electric waves between the dust grains, which increased their electrical cohesion. In this way the tube took the name of `coherer '(coherent).

[614] S.Galdabini, G.Giuliani, *Physics in Italy between 1900 and 1940* , "Historical studies in the Physical and Biological Sciences", 19 (1988), pp.115-134

[615] G. Dragoni, *Aspects of the process of growth of scientific knowledge: the conquest of the TSF against the background of Italian physics in the second half of the nineteenth* century , in *Proceedings of the VIII National Congress of History of Physics* , edited by F.Bevilacqua (Milan, 1988).

[616] E.Branly, *Variation de* conducibilité *sous diverses influences electriques* , in *Comptes rendus des Sciences de l'Académie des Sciences* , CXI, (1890), p.785.

[617] Marconi, for his part, never said from which source the knowledge of the coherer had derived. But it was wide of praise for Branly, perhaps interested, and certainly imprudent, because the French myth that made Branly the authentic inventor, not only of the coherer, but of the entire TSF, was also built on those awards.

[618] But even here Professor Calzecchi would have used the blue pencil: "almost simultaneously" (almost simultaneously) should be corrected with "six years before"; six years during which Hertz had provided the key to interpreting the action of the spark, but which Branly could not find, uncertain between the visible light of the spark and the em waves of the discharge.

The question was decided in England, after a lively debate, by Professor O. Minchin and by O. Lodge.

Giorgio Tabarroni's contributions have made plausible the thesis that the coherer was presented to Marconi by Professor Vincenzo Rosa in Livorno: and in this case it can only be the Calzecchi tube. See: G. Tabarroni, *The physicist Vincenzo Rosa and the filing tube,* in *The conquest of wireless telegraphy. Temistocle Calzecchi Onesti and the coeher* , edited by E. Fedeli and M. Guidone (Bologna 1987)

On the main page